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METHODS OF OPERATING EFFICIENCY IMPROVEMENT OF THE SECONDARY SETTLING TANKS

The results of hydraulic and technological research on the operation of various secondary settling tanks are presented. It has been proved experimentally that hydraulic coefficients of performance in vertical and radial settling tanks do not exceed 30 and 45%, respectively. The results of technological tests reveal the negative effect of density flows on sedimentation in these tanks. The major part of the settling zone is occupied by semi-stagnant and vortex zones caused by density flows. This deteriorates significantly the effluent quality. Negative effect of density flows is eliminated in settling tanks equipped with the rotating bottom distributing device and developed water collecting system. The velocity of the density flow propagation in the settling tank is decreased by supplying the sludge layer with mixed liquor and due to the movement of the bottom rotating distributing device, its velocity being equal to that of the propagation of density flow but the direction opposite.

The results have revealed that hydraulic coefficient of performance of such a tank is equal to 80–90%, exceeding 2–3 times that of conventional facilities. Elimination fo density flows permitted us to improve substantially hydraulic regime in the facility and to create optimal conditions for sedimentation in the tank's volume.

Due to double reduction of hydraulic depth with respect to that of radial settling tanks and to simultaneous 1.5–2 times increase of capacity, this design is more cost effective and promising.

Secondary settling tanks of various types are widely used in the system of facilities for biological treatment of wastewaters.

They perform several functions: separation of mixed liquor, clarification of supernatant and thickening of settled sludge. These functions must be interrelated in such a way as to ensure the necessary degree of the returned sludge thickening sufficient for maintaining a given concentration of biomass in aeration tanks at the lowest content of the effluent solids.

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The other conditions (such as the sludge volume index (SVI), the sludge concentration in the aeration tank and the wastewater temperature) being equal, SS concentration in the effluent depends on the hydraulic conditions in the settling tank ensured by the type of sludge-distributing and water-collecting devices.

In the treatment facilities constructed in the USSR, the employed settling tanks are vertical, rectangular and radial. Schemes of these facilities are given in fig. 1. Vertical settling tanks are used in the treatment facilities of low capacity, radial and rectangular

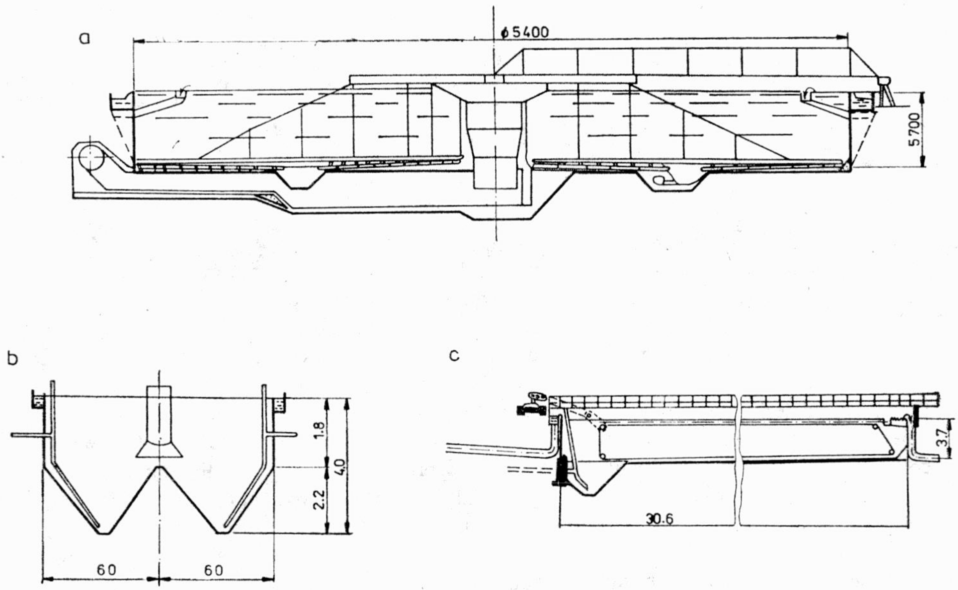

Fig. 1. Diagrams of secondary settling tanks
Rys. 1. Schematy osadników wtórnych

ones being employed at aeration stations of medium and high capacities. Radial settling tanks are most often employed because of their operation reliability and systematic removal of sludge by sludge suckers or sludge scrapers. They, however, are characterized by unsteady turbulent conditions which are affected by density and convective flows. These disadvantages of radial settling tanks become doubled during separation of mixed liquors the density of which is higher than that of the effluent in the settling tank.

Studies on hydraulic conditions of radial secondary settling tanks were carried out at the VODGEO Institute where a number of municipal and industrial treatment facilities were investigated, using the method of tracing by a fluorescent and a radioactive isotope. The analysis of the obtained data permitted us to evaluate the degree of hydraulic imperfection of settling tanks. For radial settling tanks of diameters of 20–40 m, their capacity expressed by the ratio of real retention time to the designed one ranges within 0.3–0.45. It means that 55–70% of the settling tank volume is occupied by practically stagnant zones.

Distribution of SS concentration in the settling tank volume (fig. 2), being in the central part 2–3 times lower than in the working flow from the settling tank, indicates the imperfection of hydraulic conditions, i.e. that the upper central part is semi-stagnant. The working flow is carried by the density flow down to the bottom and, moving towards the periphery, occupies about 1/3 of the tank volume. After having reached the edge of the tank at a high velocity, the working flow is reflected and generates an intense circulation and a counter flow in the upper part of the settling tank. In the vortex zone under the collecting weir the SS concentration increases, some part of SS being carried out with the effluent.

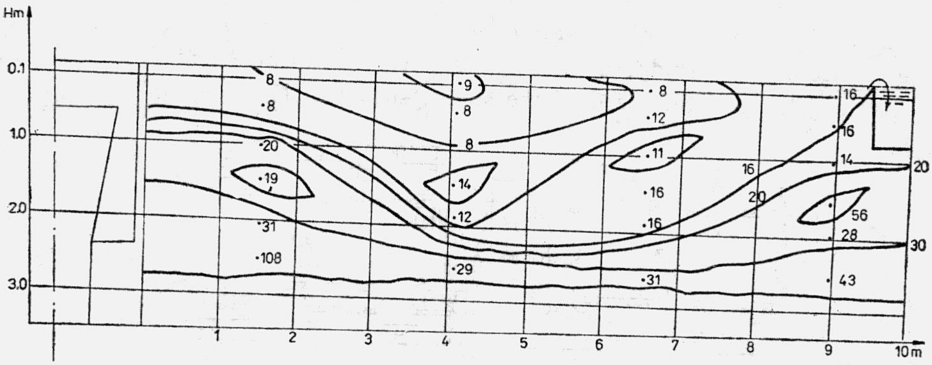

Fig. 2. Field of concentrations in a radial settling tank, $D = 20$ m
Rys. 2. Pola stężeń w osadniku promieniowym, $D = 20$ m

Density flows also affects substantially the hydraulic conditions in vertical settling tanks. Mixed liquor having entered the unit spreads about the more thickened sludge blanket, strikes against the edge and generates a circular flow, which rapidly reaches the surface of the settling tank, and the working flow overflows into the collecting trough. The efficiency of the vertical secondary settling tanks is equal to 0.25–0.3. The characteristic feature of standard structures of these facilities is the sludge deposition on the slopes and in the corners of sludge hoppers hampering their maintenance.

The negative effect of density flows is in a way characteristic of rectangular secondary settling tanks.

Hydraulic conditions of secondary settling tanks may be distinctly improved in two ways: 1) by decreasing the difference between the density of feeding mixed liquor and that of influent remaining in the settling tank and 2) by applying rotating sludge distributing devices since then the density flow is eliminated by the distributing device moving in the opposite direction. The first method can be realized by feeding the mixed liquor directly into the sludge blanket.

After preliminary research carried out on the model, this method was verified in one of the operating secondary settling tanks installed in treatment facilities of a chemical complex. To this end one of the conventional settling tanks was transformed into a tank equipped with the rotary bottom distributing device and a surface water-collecting device. The scheme is given in fig. 3. Mixed liquor is fed by means of a sag pipe *1* to the central rotating chamber *2*. The chamber is connected with two sludge-distributing pipes located near the bottom of the tank. Jet-cutting segmental diaphragms *5* are installed close to the outlets *4* of sludge-distributing pipes. Jet-guiding blades *6* are fixed on the pipe behind the outlets. Thickened and settled activated sludge is collected by two sludge suckers *7*.

The clarified effluent is collected in four radially located submerged pipes *8* connected with the rotating central chamber *9* for clarified water. Rotating parts of the central chamber are connected with the lower parts through air valves *5* fed continuously with air. The excess air is discharged into the atmosphere through special pipe sockets. The design of water collecting and sludge distributing devices ensures an equal detention time of each separate jet. Rotation speed of the sludge sucker is 17.5 rev/min.

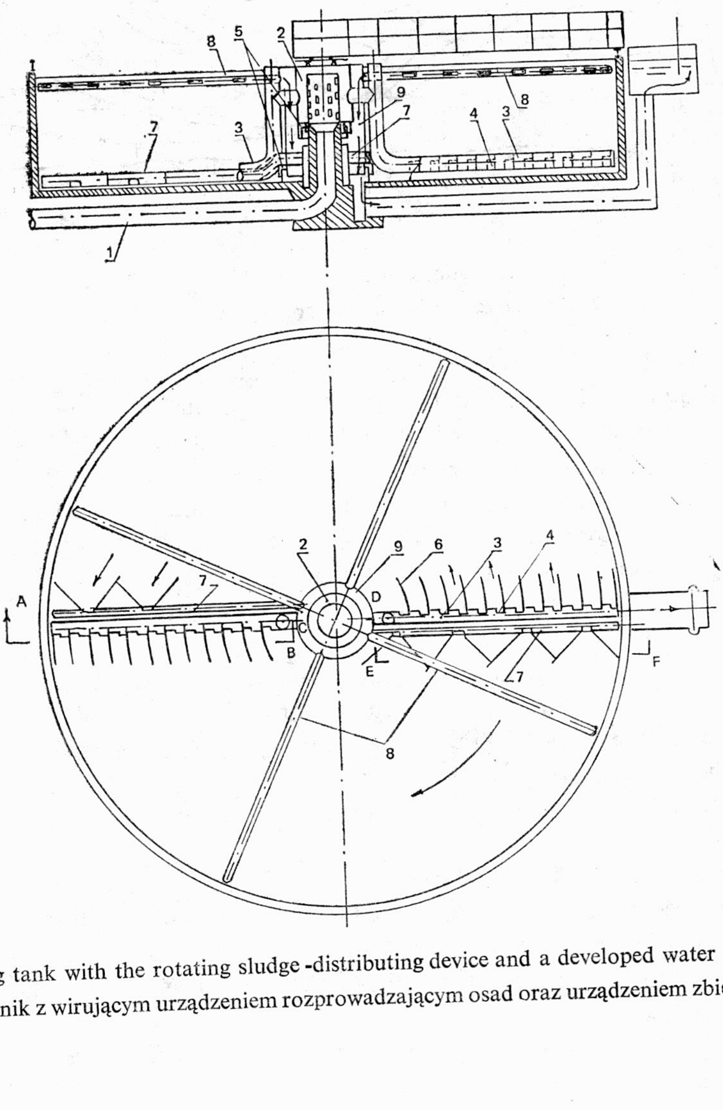

Fig. 3. Settling tank with the rotating sludge -distributing device and a developed water collecting device

Rys. 3. Osadnik z wirującym urządzeniem rozprowadzającym osad oraz urządzeniem zbierającym wodę

The settling tank with the rotating bottom distributing device operates steadily uuner hydraulic conditions varying from 0.5 to 2.1 m/h. Effluent solids do not exceed 10 mg/dm³. During investigations the sludge concentration in the aeration tank varied from 1,1 to 1.6 g/dm³, the SVI being equal to 96–166 cm³/g. The highest load of the solid phase was 3.2 kg/m² hour.

Studies of hydraulics and the concentrations have shown the absence of density flows in the settling tank. The efficiency of the settling zone is 0.85–0.95.

The automatic system for sludge and water level stabilization in the settling tank simplifies sufficiently the maintenance of the unit.

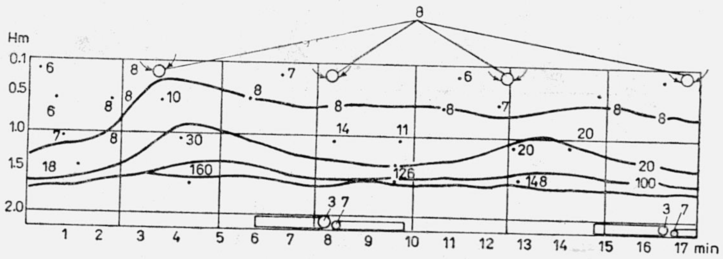

Fig. 4. Field of concentrations in a settling tank with the bottom distribution

Rys. 4. Stężenia w osadniku o rozdzielaniu dennym

The investigations and the experience gained in maintenance of the radial settling tanks proved the presence of semistagnant zones (in the central part of the unit) and vortex zones of high velocities caused by density flows. These phenomena were investigated in radial settling tanks of various diameters (20, 24 and 40 m). The SS concentration in the central part of the settling tank is 2–3 times lower than that in the effluent. The same situation was observed during investigations of vertical settling tanks.

In order to compare the operation parameters of various secondary settling tanks, the following relationship can be used:

$$C_t = f(q_r,\ IC_a)$$

where:

C_t — effluent solids, mg/dm³,

I — sludge volume index, cm³/g,

C_a — sludge concentration in the aeration tank, g/dm³.

The product IC_a is a generalized criterion characterizing settling properties of various activated sludges. This relationship for secondary settling tanks is given in fig. 4. From this figure it follows that the settling tank with the bottom distributing device is affected by variations of the hydraulic load. These facilities operate steadily at the load ranging from 0.1 to 0.48 m³/m² h, while the other types at the normal effluent solids do not withstand the loads higher than 0.2–0.3 m³/m² h.

Better operating parameters of settling tanks with the bottom distributing device are due to special hydraulic conditions. These facilities can be used at 3–5 g/dm³ MLSS concentrations when the effect of density is very considerable.

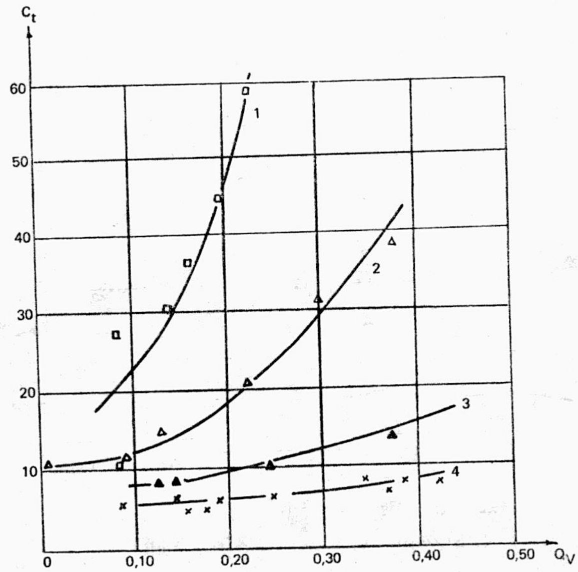

Fig. 5. Sludge content in the effluent from secondary settling tanks of various types depending on the loading

1 – vertical, settling tanks, *2–3* – radial settling tanks, *4* – settling tank with the bottom rotating distributor

Rys. 5. Zawartość osadu w odcieku z osadników wtórnych różnych typów w zależności od obciążenia

1 – osadniki pionowe, *2–3* – osadniki promieniowe, *4* – osadnik z wirującym rozdzielaczem dennym

CONCLUSIONS

1. Hydraulic conditions of the secondary settling tanks affect significantly their operation efficiency. Due to the density flows in vertical and rectangular settling tanks, the volume used does not exceed 40%.

2. By eliminating the density flows by means of rotating distributing devices, the volume used may increase to 80–90%, the highest percentage will be obtained by using bottom rotating distributing devices.

3. The capacity of secondary settling tanks can be increased by improvement of their hydraulic conditions. Thus, the hydraulic load in settling tanks with the bottom rotating distributor reaches 2.2 m³/m²/h at normal effluent solids up to 20 mg/dm³ which exceeds almost 2 times the load in radial settling tanks.

4. Operation of new secondary settling tanks was tested under full-scale conditions. These facilities are recommended for a number of treatment plants. In treatment plants of the capacity of 100,000 m³/day they will give the economic benefit of 140,000 rubles per year.

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METODY ZWIĘKSZANIA WYDAJNOŚCI OSADNIKÓW WTÓRNYCH

Przedstawiono wyniki hydraulicznych i technologicznych badań eksploatacyjnych różnych typów osadników wtórnych. Wykazano doświadczalnie, że współczynniki hydrauliczne osadników poziomych i radialnych nie przekraczają odpowiednio 30 i 45%. Badania technologiczne wykazały negatywny efekt przepływów gęstościowych na przebieg sedymentacji. Główną część strefy sedymentacji osadnika zajmują obszary cieczy stojącej i obszary zawirowań wywołanych przepływami gęstościowymi. Obniża to znacznie jakość wody wypływającej z osadnika.

Ten negatywny efekt przepływów gęstościowych można wyeliminować wyposażając dno osadnika w obrotowe urządzenie rozprowadzające ciecz i odpowiedni system odbierania wody. Szybkość rozprzestrzeniania się przepływu gęstościowego w takim osadniku redukowana jest dzięki dopływowi cieczy do warstwy osadu oraz ruchowi obrotowemu urządzenia rozprowadzającego na dnie osadnika. Szybkość obrotów tego urządzenia dostosowana jest do szybkości propagacji przepływu gęstościowego lecz skierowana przeciwnie.

Stwierdzono, że hydrauliczne współczynniki eksploatacyjne takiego osadnika osiągają wartość 80–90%, a więc przewyższają 2–3 krotnie wartości uzyskiwane w urządzeniach konwencjonalnych. Eliminacja przepływów gęstościowych usprawnia zasadniczo hydrauliczne warunki pracy urządzenia i stwarza optymalne warunki sedymentacji w całej objętości osadnika.

Dzięki dwukrotnej redukcji głębokości hydraulicznej w porównaniu z osadnikami radialnymi oraz dzięki równoczesnemu, 1,5–2 krotnemu wzrostowi wydajności zaprojektowany osadnik jest rozwiązaniem obiecującym z punktu widzenia kosztów eksploatacyjnych.

METHODEN ZUR ERHÖHUNG DER KAPAZITÄT VON NACHKLÄRBECKEN

Angeführt werden hydraulische und technologische Betriebsergebnisse von verschiedenen Nachklärbecken. Man konnte nachweisen, daß hydraulische Koeffiziente von längs durchflossenen und von Radialbecken 30 und 45% nicht überschreiten. Technologische Untersuchungen haben den negativen Einfluß

der Dichteströmungen auf den Sedimentationsverlauf erwiesen. Den Hauptteil der Sedimentationszone im Klärbecken nehmen Toträume mit stehender Flüssigkeit ein, sowie Wirbelräume, die durch die Dichteströmung verursacht sind. Das aber beeinflusst in ungünstiger Weise die Qualität des Abflusses.

Die negativen Erscheinungen der Dichteströmungen kann man vermeiden, wenn auf der Beckensohle entsprechende, drehbare Verteilungseinrichtungen und ein entsprechendes Wasserabnahmesystem installiert werden. Die Geschwindigkeit der Dichteströmung kann durch den Zufluß der Flüssigkeit in die Schlammschicht sowie aufgrund der Drehbewegung der Verteilungseinrichtung gesteuert werden. Die Drehgeschwindigkeit der Verteilungseinrichtung sollte mit der Propagationsgeschwindigkeit der Dichteströmung übereinstimmen, zu der letzten aber entgegengerichtet sein.

Die hydraulische Leistung eines solchen Absetzbeckens beträgt 80–90% und ist dementsprechend 2–3 mal so hoch wie die der konventionellen Einrichtungen. Die Eliminierung von Dichteströmungen ergibt optimale Bedingungen für das Absetzen der Schwebestoffe im ganzen Beckenvolumen.

Dank einer Halbierung der hydraulischen Beckentiefe im Vergleich zu normalen Radialbecken und einer gleichzeitigen 1,5 bis 2-maliger Erhöhung der Kapazität, ein solch neuartiges Klärbecken ist in Betracht von Betriebskosten erfolgversprechend.

МЕТОДЫ ПОВЫШЕНИЯ ЭФФЕКТИВНОСТИ ВТОРИЧНЫХ ОТСТОЙНИКОВ

Представлены результаты гидравлических и технологических эксплуатационных исследований различных типов вторичных отстойников. Доказано опытным путём, что гидравлические коэффициенты горизонтальных и радиальных отстойников не превышают соответственно 30 и 45%. Технологические исследования показали отрицательный эффект плотностных течений на ход процесса седиментации. Главную часть зоны седиментации отстойника занимают области стоячей жидкости и области вращений потока, вызванных плотностными течениями. Это значительно снижает качество воды, вытекающей из отстойника.

Этот отрицательный эффект плотностных течений можно элиминировать, снабжая дно отстойника поворотной установкой, разводящей жидкость и соответствующей системой водоприёма. Скорость распространения плотностного течения в таком отстойнике уменьшается благодаря притоку жидкости в слой ила, а также благодаря движению поворотной разводящей установки на дне отстойника. Скорость оборотов этой установки приспособлена к скорости распространения плотностного течения, но направлена в противоположном направлении.

Отмечено, что гидравлические эксплуатационные коэффициенты такого отстойника достигают значения 80–90%, т. е. превышают в 2–3 раза значения, достигаемые в традиционных установках. Элиминирование плотностных течений принципиально улучшает гидравлические рабочие условия установки и создаёт оптимальные условия седиментации во всём объёме отстойника.

Благодаря двукратному уменьшению гидравлической глубины по сравнению с радиальными отстойниками, а также благодаря одновременному 1,5–2-кратному повышению производительности, запроектированный отстойник является многообещающим с точки зрения эксплуатационных расходов.